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Seasonal variation of residence time in spring and groundwater evaluated by CFCs and numerical simulation in mountainous headwater catchment

Maki Tsujimura (1), Yasuto Watanabe (1), Koichi Ikeda (1), Shinjiro Yano (2), and Yutaka Abe (2)

(1) University of Tsukuba, Faculty of Life and Env Sci, Tsukuba, Japan (mktsuji@geoenv.tsukuba.ac.jp), (2) Suntory Global Innovation Center

Headwater catchments in mountainous region are the most important recharge area for surface and subsurface waters, additionally time information of the water is principal to understand hydrological processes in the catchments. However, there have been few researches to evaluate variation of residence time of subsurface water in time and space at the mountainous headwaters especially with steep slope. We investigated the temporal variation of the residence time of the spring and groundwater with tracing of hydrological flow processes in mountainous catchments underlain by granite, Yamanashi Prefecture, central Japan.

We conducted intensive hydrological monitoring and water sampling of spring, stream and ground waters in high-flow and low-flow seasons from 2008 through 2013 in River Jingu Watershed underlain by granite, with an area of approximately 15 km2 and elevation ranging from 950 m to 2000 m. The CFCs, stable isotopic ratios of oxygen-18 and deuterium, inorganic solute constituent concentrations were determined on all water samples. Also, a numerical simulation was conducted to reproduce of the average residence times of the spring and groundwater.

The residence time of the spring water estimated by the CFCs concentration ranged from 10 years to 60 years in space within the watershed, and it was higher (older) during the low flow season and lower (younger) during the high flow season. We tried to reproduce the seasonal change of the residence time in the spring water by numerical simulation, and the calculated residence time of the spring water and discharge of the stream agreed well with the observed values.

The groundwater level was higher during the high flow season and the groundwater dominantly flowed through the weathered granite with higher permeability, whereas that was lower during the low flow season and that flowed dominantly through the fresh granite with lower permeability. This caused the seasonal variation of the residence time of the spring water, older in low flow season and younger in the high flow season in the watershed. As a result, the numerical model simulated successfully the dynamics of the groundwater flow and residence time in the spring water.